Highly-Integrated Submillimeter-Wave Radiometric Receivers based on 25-nm InP HEMT Low-Noise Amplifiers

6-13-2017

Presented by Bill Deal

William R. Deal, Pekka Kangaslahti*, Alex Zamora,

Kevin Leong, Erich Schlecht*, Gerry Mei, and Steven C. Reising**

Northrop Grumman, Jet Propulsion Laboratory*

and Colorado State University**

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

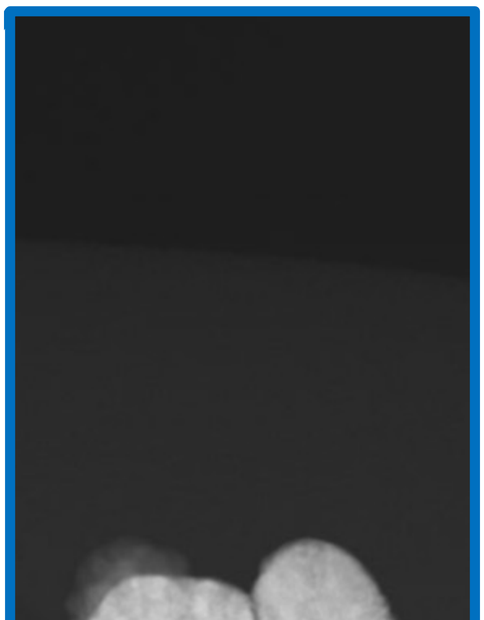
Outline

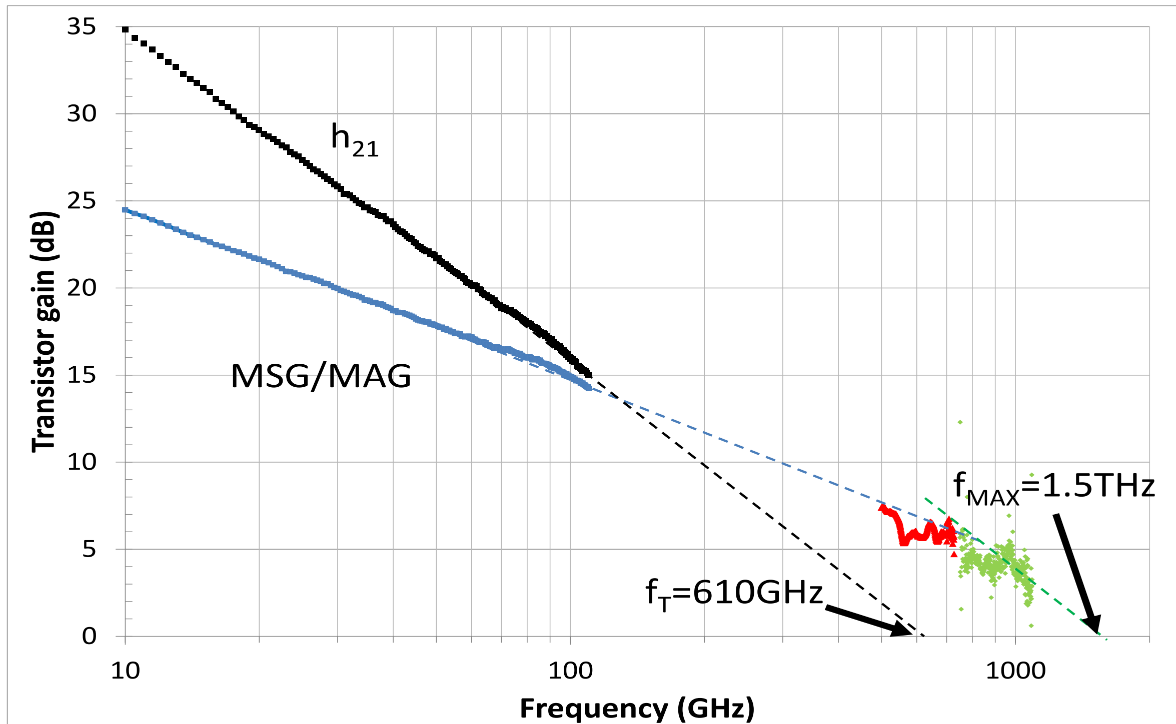
- Outline
- Motivation
- Technology Status
- Application of 25 nm InP HEMT to Communications
- 2^{nd} MMIC Iteration (TWC2) Status
- 670 GHz Receiver Status
- Conclusion

Motivation

Scaling enables significantly enhanced performance

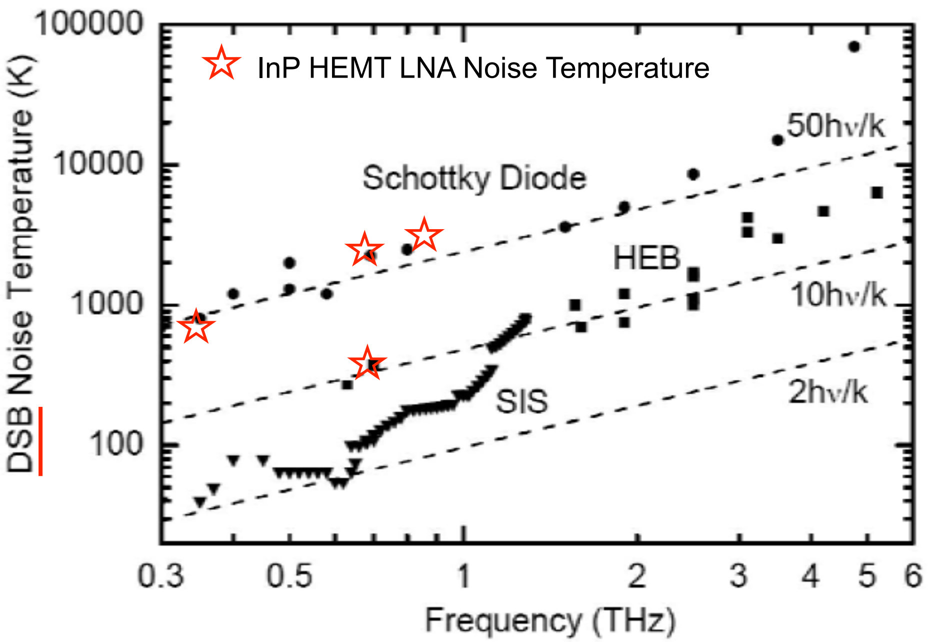
- 25 nm gatelength
- f_{max}: 1.5 THz
- f_T: 0.61 THz





Submillimeter LNA's

Mixer DSB Noise Performance



Q: How Do InP HEMT LNA-based Front Ends Compare to Mixer-based Front Ends?

- **InP HEMT LNA sensitivity approaches that of DSB mixers.**
- **InP HEMT LNA is superior to that of mixers operated in SSB mode.**
- **This extends to cryogenic operation.**

670 GHz Comparison

	Ambient Temperature [K]	Noise Figure [dB]	Noise Temperature [K]
HEMT	270 25	9.6 3.8	2355 400
GaAs Schottky	270	9.4 DSB (12.4 SSB*)	2236 DSB (4750 SSB*)
HEB	Cryo	2.7 DSB (5.7 SSB*)	250 DSB (788 SSB*)
SIS	4	1.3 DSB (4.3 SSB*)	100 DSB (491 SSB*)

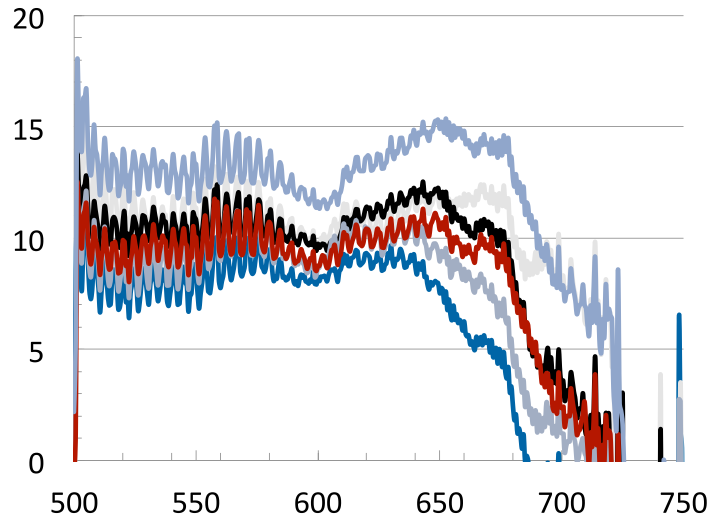
850 GHz Comparison

	Ambient Temperature [K]	Noise Figure [dB]	Noise Temperature [K]
HEMT	270	12	3361
GaAs Schottky	270	9.8 DSB (12.8 SSB*)	DSB 2500 (5236 SSB*)

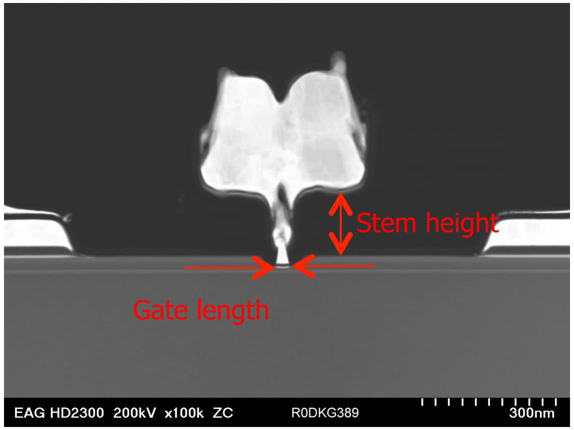
*Performance estimated from plot. SSB is calculated from DSB by adding 3 dB

2nd MMIC Iteration Results

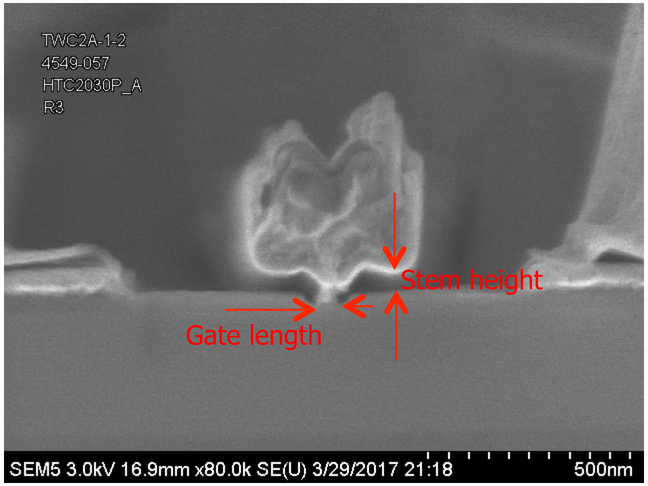
- Lower than expected circuit gain was measured from TWC2A-1.
- 670 GHz amplifiers showed poor gain.
- Lower frequency amplifiers also showed poor gain.
- Started troubleshooting 25 nm InP HEMT process:
  1. Cross-section SEM of TWC2A-1 gate
  2. Started process validation lot:
     1. Check Resist profile after the EBL process
     2. Check Resist profile after the plasma etch of the dielectric layer



Cross-section SEM of the TWC2A-1 Gate



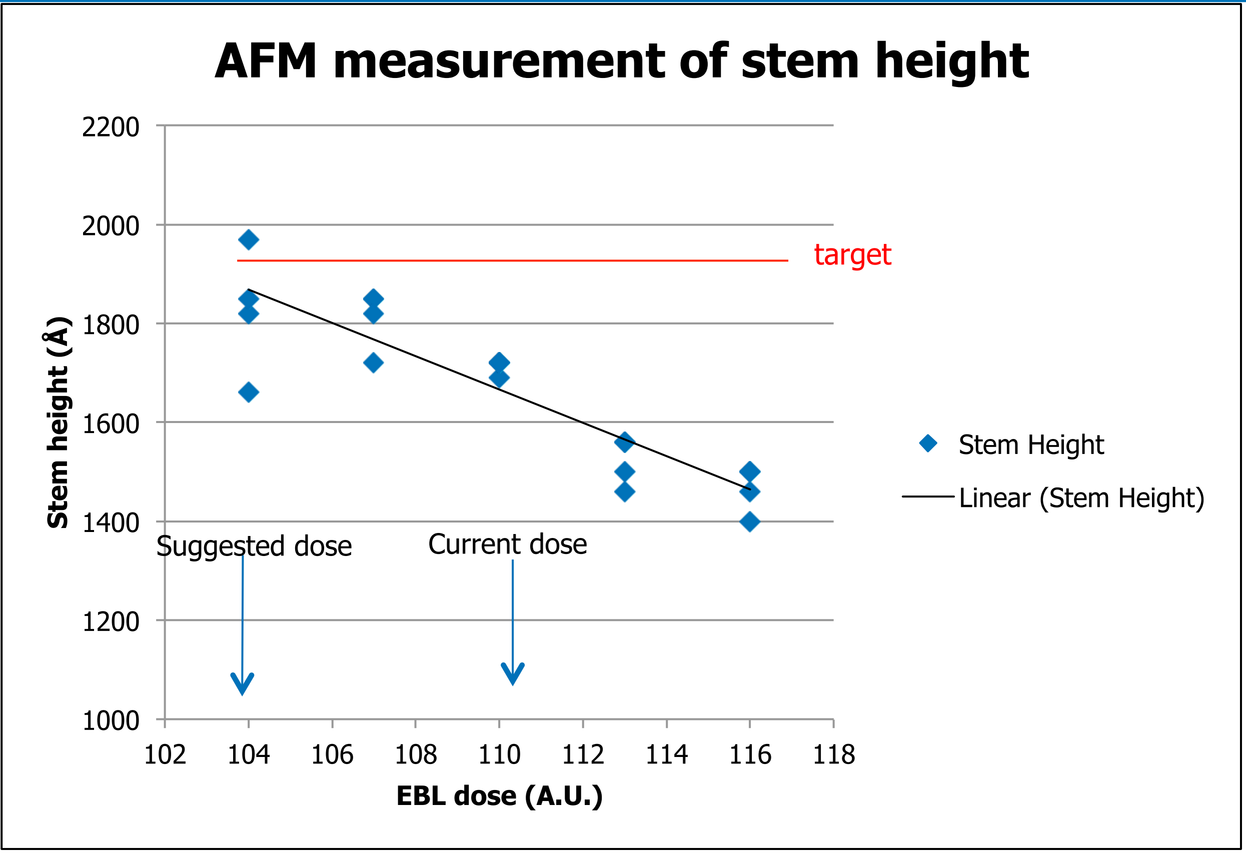
Normal 25nm gate

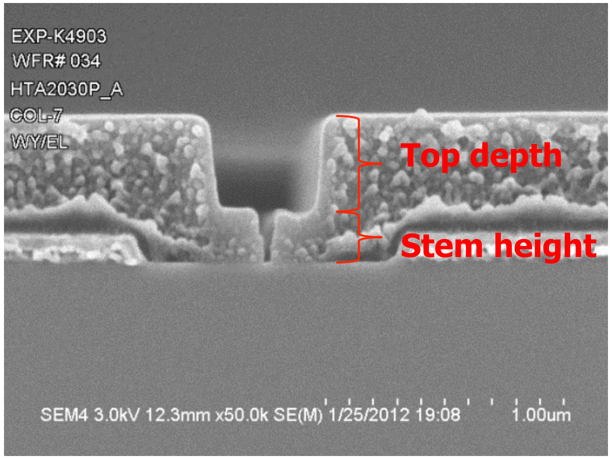


TWC2A-1

- TWC2A-1 has shorter stem height and larger gate length than a normal 25nm gate.

Stem Height Measurement after EBL Process





- The EBL dose needs to be adjusted lower to reach the target stem height.

THz Data Link Overview

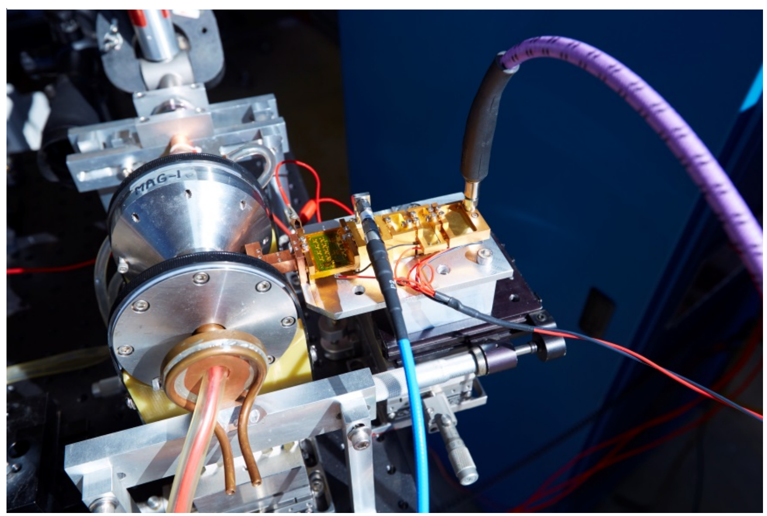
- Significant advances over last decade in submillimeter wave electronics
  - Transistor based low noise amplifiers, receviers and transmitters proven to 850 GHz
  - Vacuum tube electronics (TWTs) to 1,000 GHz

- Link calculations show space base Leo links are possible with current capabilities

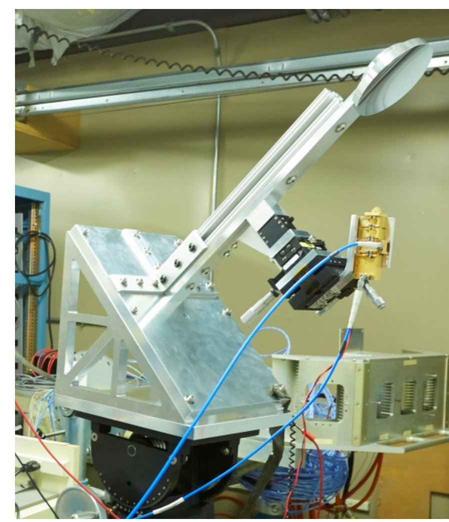
- What is possible on the ground?

100 G Modulator

THz Electronics TX (with TWT)

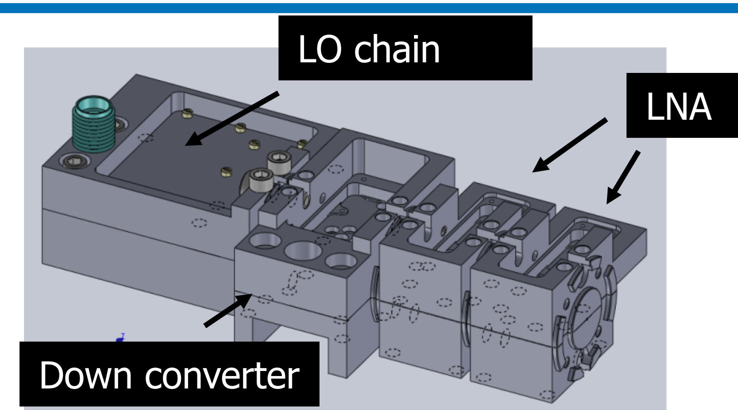


RX with Reflector

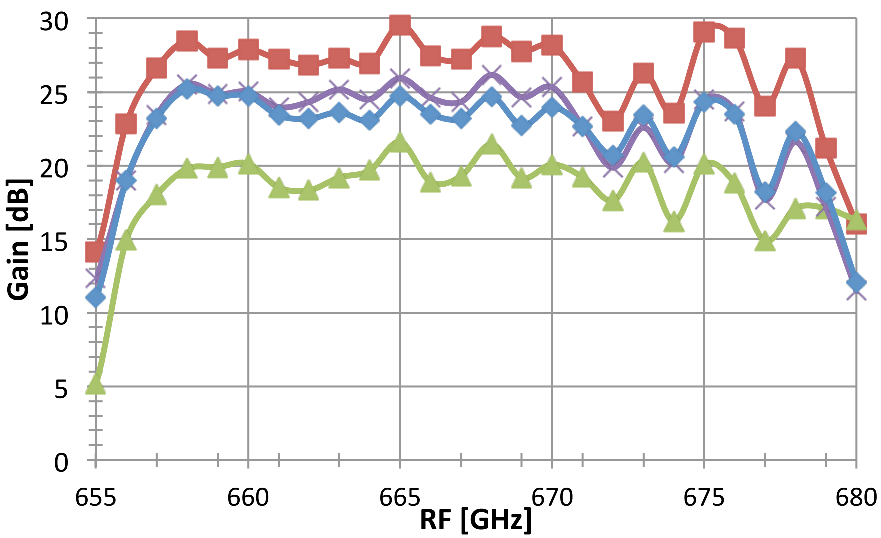


Receiver (NGAS, Redondo Beach)

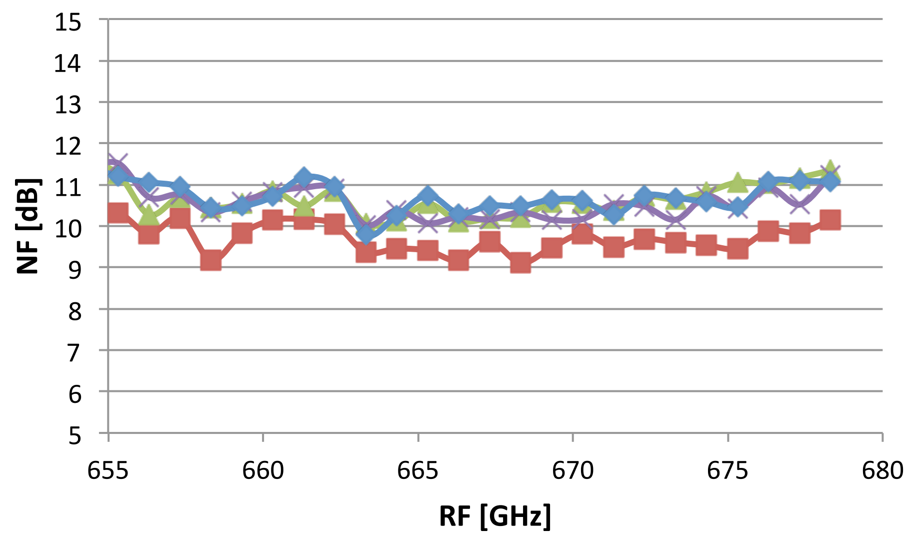
- ~25 dB Gain and 10 dB NF
- Bandwidth ~ 20 GHz
- Limited by IF mixer bandwidth



Measured Gain

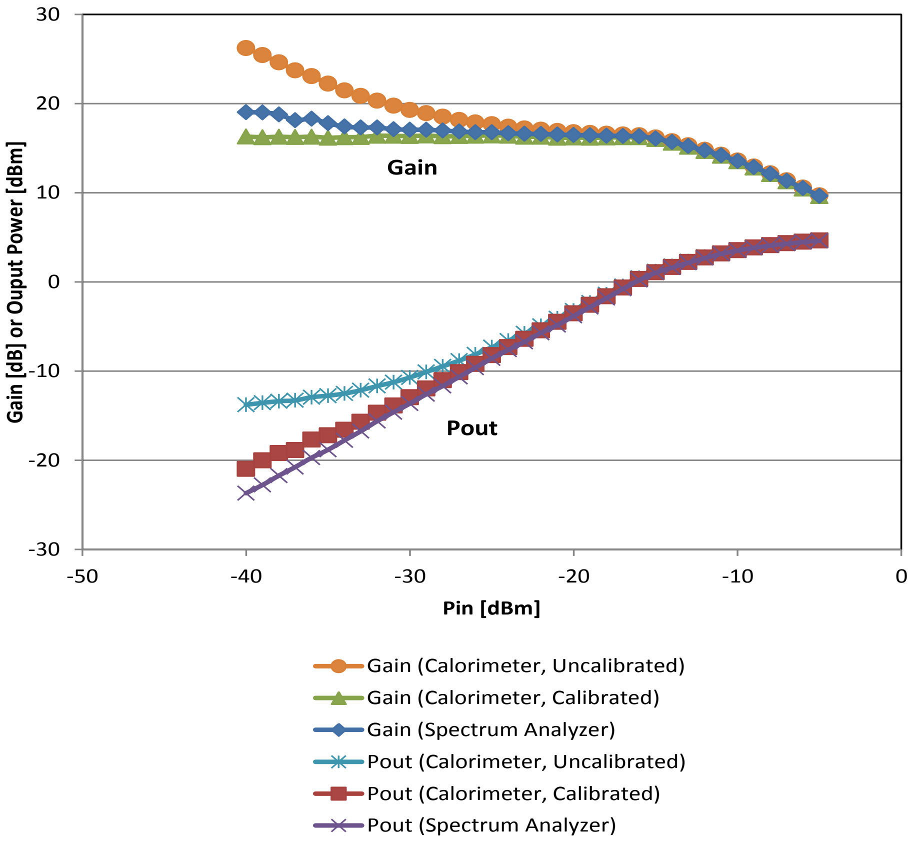


Measured Noise Figure



Exciter (NGAS, Redondo Beach)

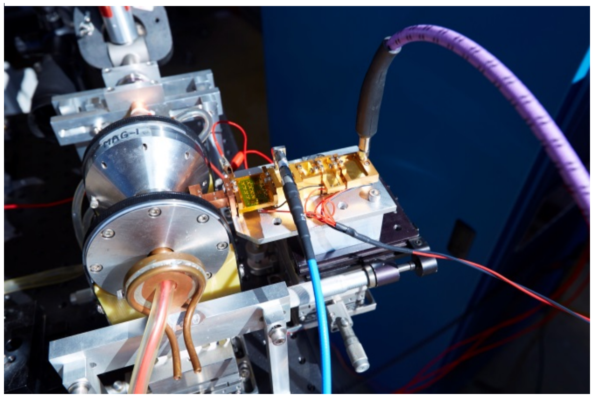
- Heterodyne up-converter
- 16 dB small signal gain
- 6 dBm saturated output power



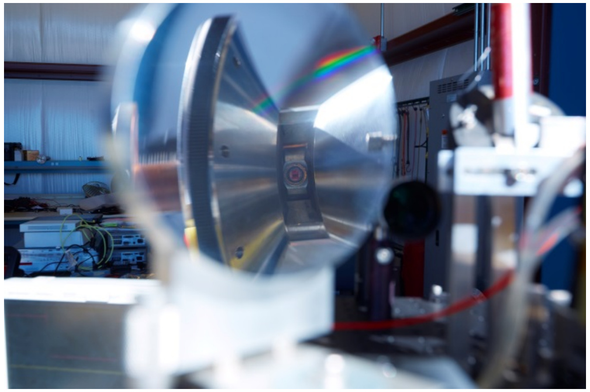
TWT (NGMS, Rolling Meadows)

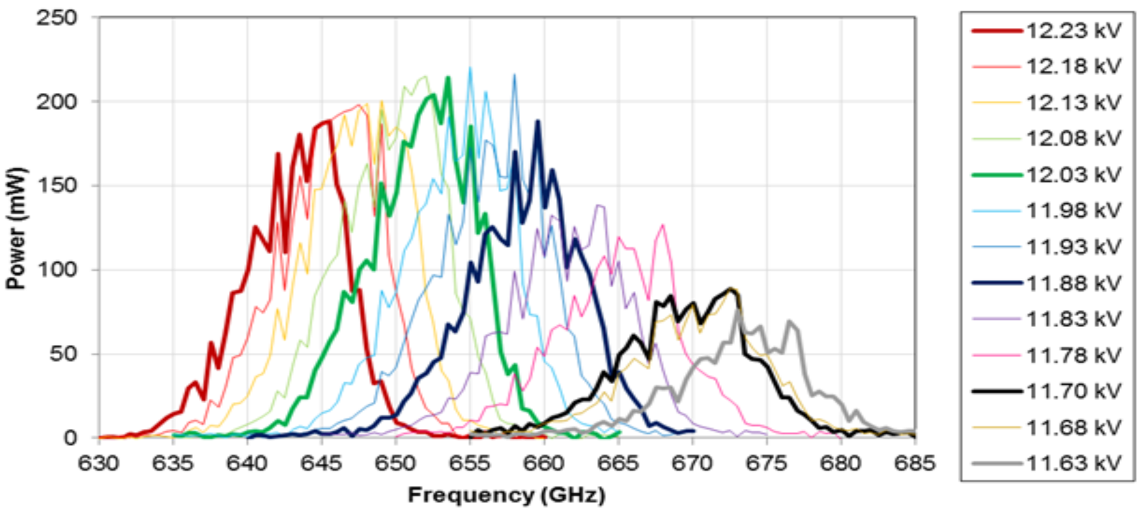
- Peak power of 200 mW
- >100 mW available at demo frequency (666 GHz)
- Tuneable with voltage
- Integrated with frequency converter (exciter and SSPA) and 10 cm reflector

TWT with exciter



Reflector and Window

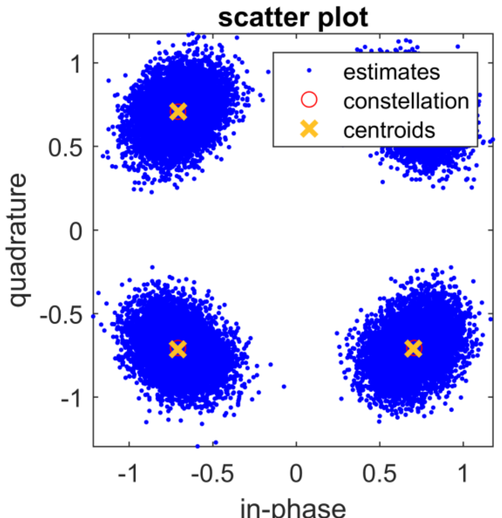




Results: 600 M

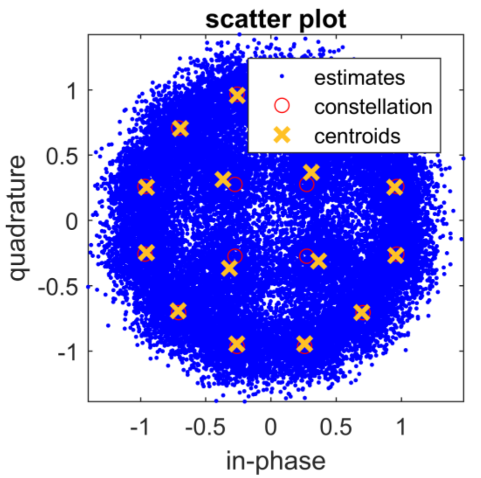
- Successfully received and demodulated QPSK
- Error rate on 16-APSK is higher
- May be at least partially attributed to swapped mixer with higher LO leakage in band

QPSK



EVM: 19%

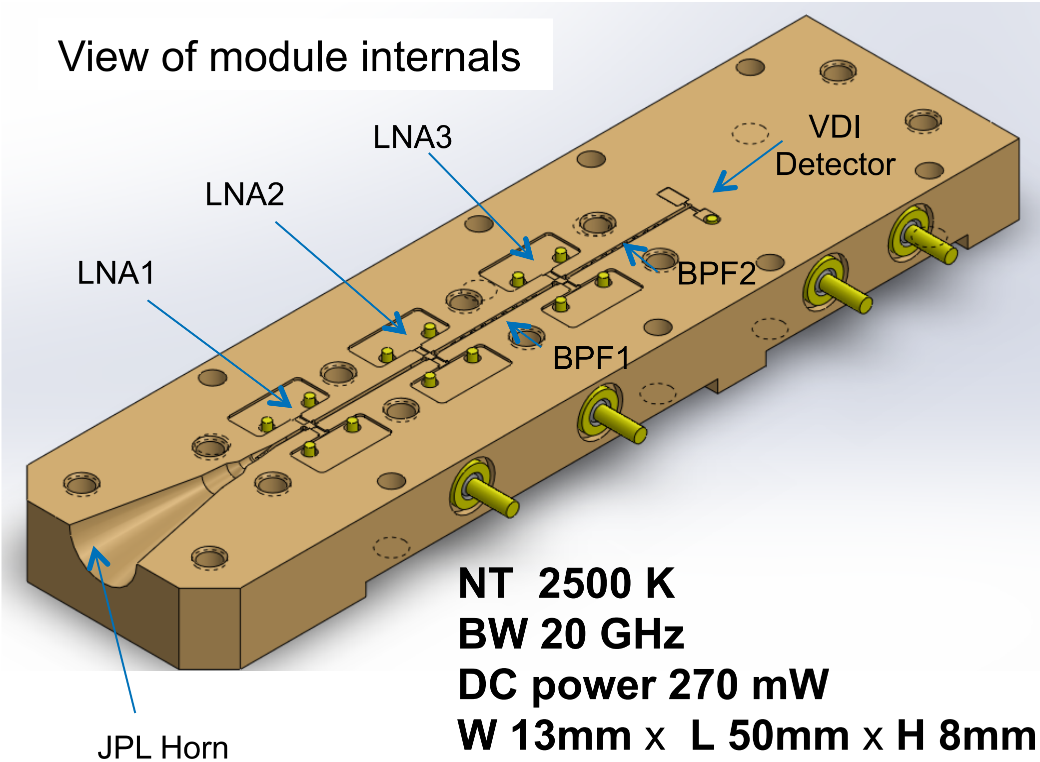
16-APSK



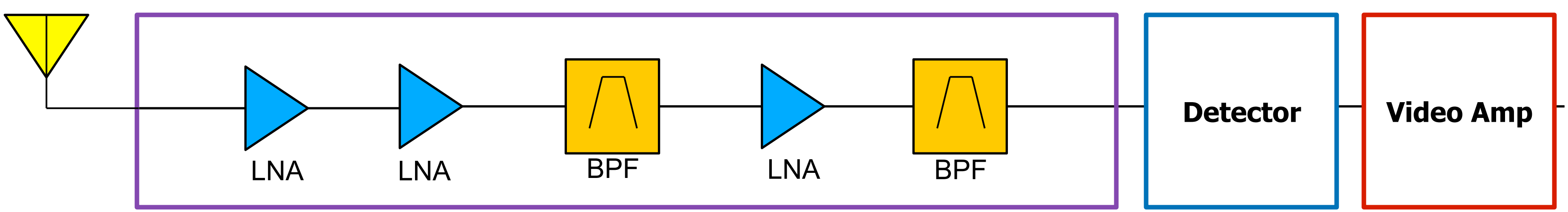
EVM: 26.6%

670 GHz Receiver

Module includes:
- Feedhorn machined in the housing to minimize waveguide length to the first LNA
- LNA MMICs with on chip transitions
- Bandpass filters
- Virginia Diodes Detector diode mounted on quartz substrate
- Video amplifier and bias electronics on the back side

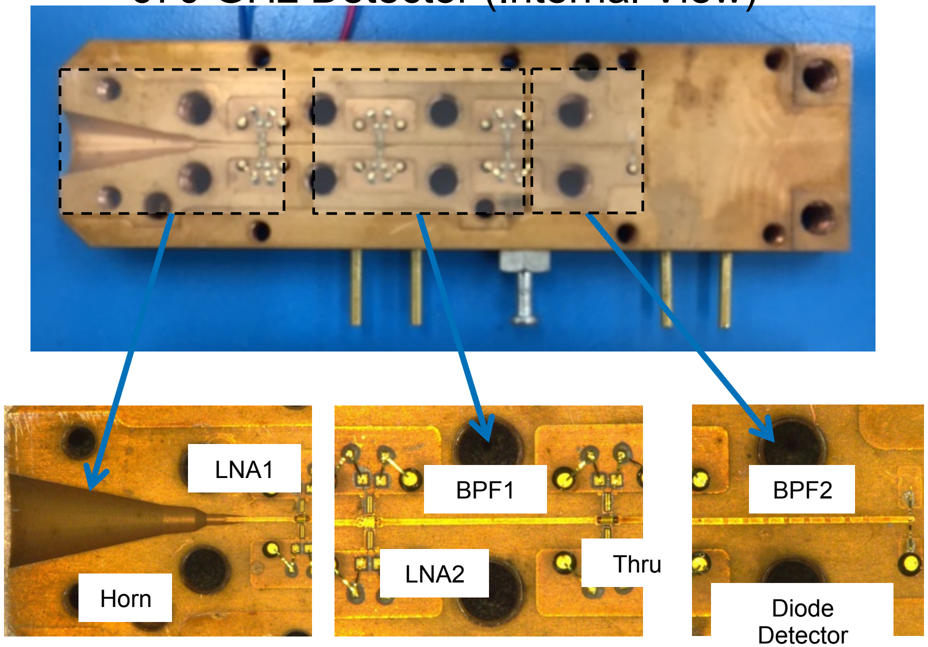


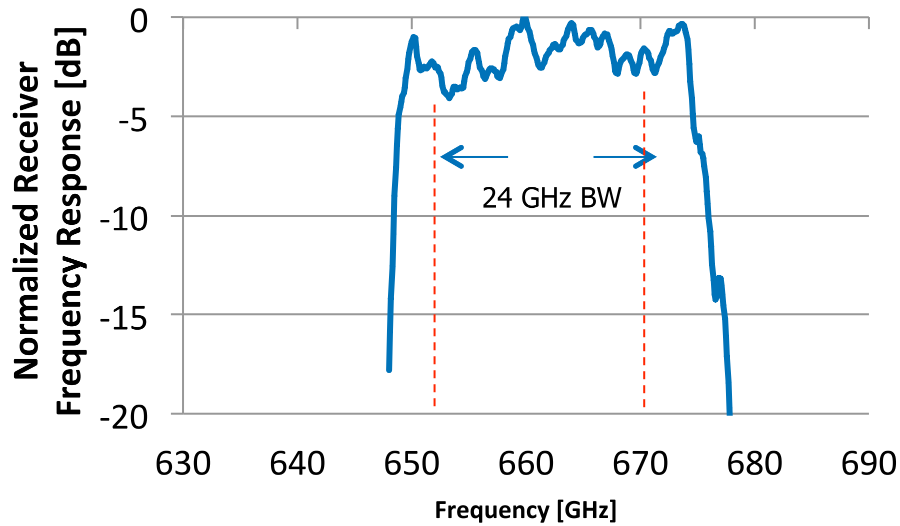
NT 2500 K
BW 20 GHz
DC power 270 mW
W 13mm x L 50mm x H 8mm



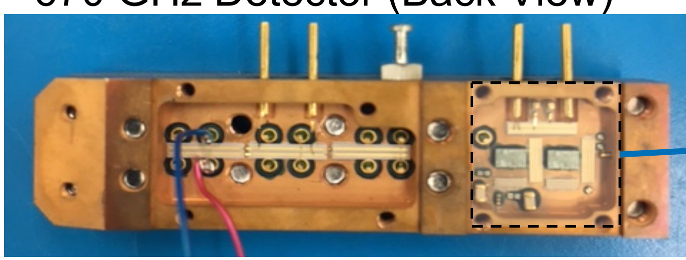
Initial 670 GHz Receiver Measurements

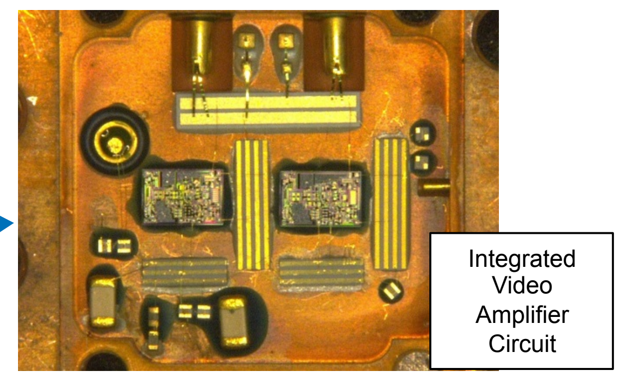
670 GHz Detector (Internal View)





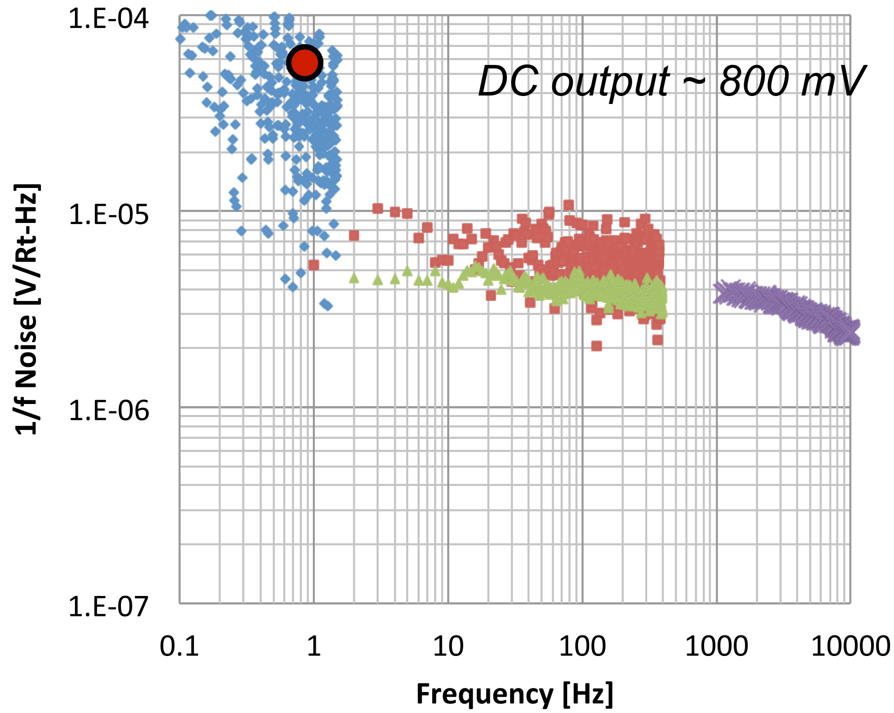
670 GHz Detector (Back View)





Side-by-Side Comparison
(Plotted Data is Not Normalized)

?V = ?G/G ~9.6E-5 @ 1 Hz



DSD Wafer Has 1/f Noise On The Order of 1E-4

Conclusion

- Direct detection 670 GHz receiver has been demonstrated for the first time.
- Some setbacks (cost/schedule) due to poor quality TWC2 wafers
- Replacement wafers being fabricated
- Will be used to complete TWICE receivers